# SCIL – A New Method for Large Area NIL

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## ABSTRACT

A new imprint technology for sub-50nm patterning will be introduced, bridging the gap between small rigid stamp application for best resolution and large area soft stamp usage with usual limited printing resolution below 200nm – SCIL Substrate Conformal Imprint Lithography is an enabling technology offering best of two worlds – large area soft stamps with repeatable sub-50nm printing capability, avoiding stamp deformation as no contact force applied, non-UV based curing at room temperature and allowing high aspect ratios even up to 1:10

The technology will be introduced, results for various applications be shown.

***Keywords***: NIL, large area imprint, non-UV based room temperature NIL-process

## 1 INTRODUCTION

NIL Nano Imprint Technology has gained an important status as patterning technology when it comes to applications that require sub-100 nm features at reasonable costs, such as optical gratings and other periodical patterns.

Basically two different stamp materials are in use, selected corresponding to the imprint area: rigid quartz stamps for best printing resolution, demonstrated printed features down to sub-10 nm [1] but on rather small areas like 10x10mm, definitely smaller than 1" due to physical limits of substrate/stamp planarization issues.

Soft PDMS stamp allow larger imprint areas up to substrate size (even up to 8" is applicable), but provide a trade-off in terms of printing resolution – small features may not be printed in a repeatable stability as the stamp allows and even requires a certain distortion in order to adapt to substrate topography. Even in a very few micron range of substrate waviness a stamp distortion takes place, what can distort patterns in the sub-100 nm range. For applications in microlenses or similar the dimensions are in the sub-mm down to 1 micron range, so not impacted by this effect.

Applications in the optical field like gratings for light tracking (planar/vertical light coupling/de-coupling) in LEDs, VCSELs etc. the pitch dimensions get into a sub-200nm range, thus being close to the limits of soft imprint stamps.

A method or material to overcome this trade-off is needed in order to further drive the use of NIL as an applicable technology.

## 2 SCIL SUBSTRATE CONFORMAL IMPRINT LITHOGRAPHY

In order to address a.m. issues an imprint method based on soft PDMS stamps was considered to provide best results. An approach that does not apply mechanical imprint forces, a rigid stamp backplane avoiding lateral deformation but still allowing bending for planarisation and de-molding was considered as applicable approach.


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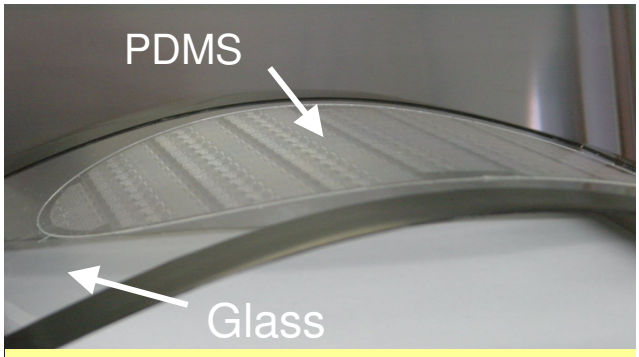
## 2.1 Material Selection

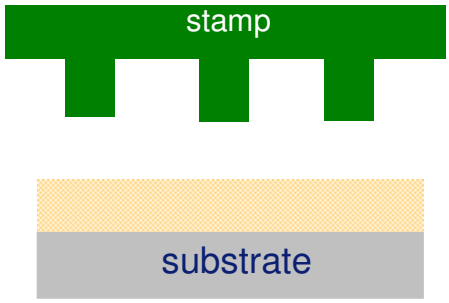
The material combination chosen is a rather thin PDMS layer of 400 – 700 µm thickness, produced by casting from a (rigid) master stamp. Additionally this PDMS-layer is attached to a 200µm glass backplane – enabling soft bending but avoiding lateral deformation of PDMS.




**PDMS stamp (6") on 200 µm AF-45**

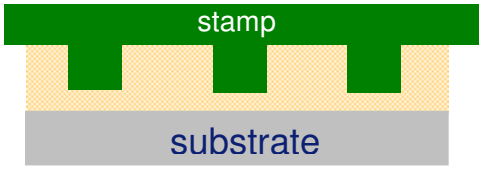
In order to avoid imprint forces an imprint material with excellent wetting properties to PDMS was chosen – allowing pattern filling by means of capillary forces. A slightly chemically modified Sol-Gel material is the choice providing the required process properties. Following sketch explains the physics of the actual SCIL imprint process:

**step 1**



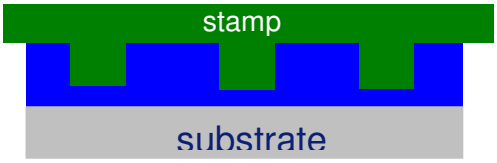

Wet sol-gel layer ~ 70nm

**Step 2**



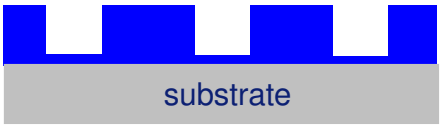

Capillary force pulls stamp into wet coating

**Step 3**




**Solvent** diffuses **into PDMS**

**Step 4**




Remove stamp from rigid sol-gel layer

## 2.2 Sol-Gel Imprint Process

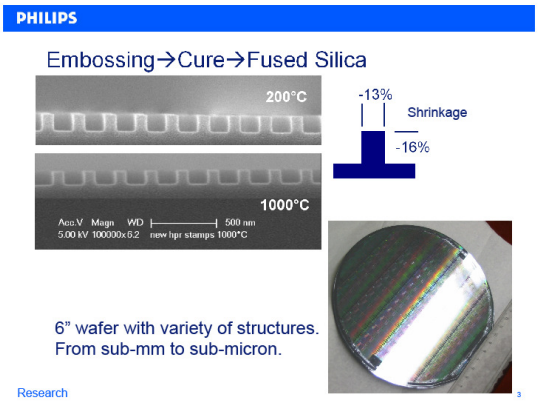
The sol-gel imprint resist contains $SiO_2$ precursors; upon application onto the substrate by spin coating the low boiling solvent evaporates.
After application of the stamp the remaining high boiling solvent diffuses in the PDMS.
Solidification can be done within 5 minutes and depends on solvent as well as resist preparation.

## 2.3 Process results

Based on the fact of solvent diffusion into the PDMS stamp the question of saturation effects arises – but due to the low amount of Sol-Gel (less than 100 nm layer thickness) compared to the PDMS stamp mass (400 – 700 µm thickness) the amount of solvent going into the stamp is neglect able, especially when considering that the time window between two imprints allow the solvent to vanish completely.

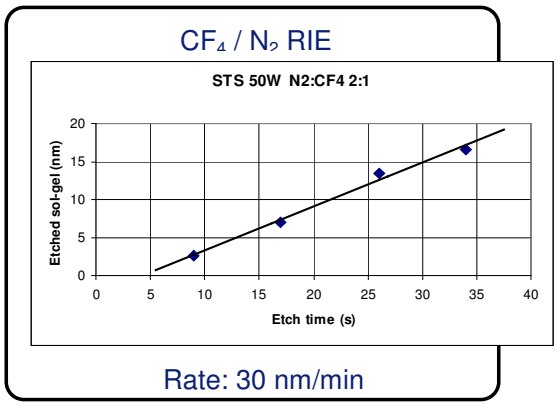
The effect of solvent transfer is expected to cause a certain shrinkage; this effect happens with a predictable amount of 7%, but only in z-direction [2].

Additional shrinkage only applies when curing the Sol-Gel above 200°C

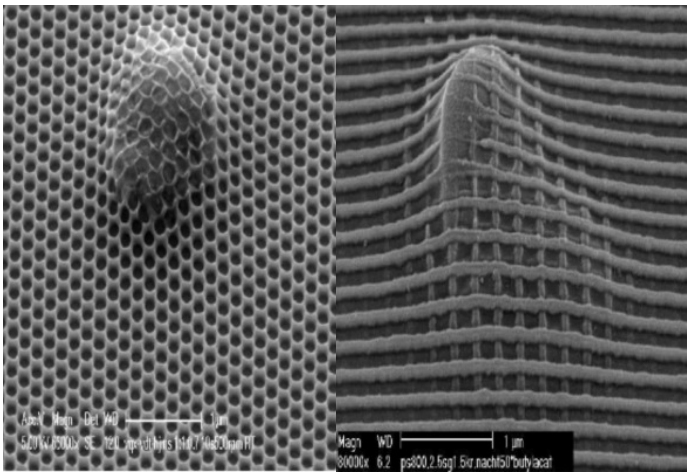



On the other hand this material allows a high temperature treatment compared to other imprint polymers that don't.

Furthermore the imprinted pattern provides excellent residual layer thickness uniformity, what can be removed with a RIE etch process and subsequently the pattern can act as etch mask into substrate or metal layers.




## 2.4 Substrate Conformal Imprints



Particles should not be the rule – but show the conformal printing capability in this images.

## 3 APPLICATIONS

The excellent performance in respect to substrate conformity and pattern fidelity over large areas (< 0,03 % pattern deviation measured over a 15x15 mm2 area [3]) makes this imprint technology to a powerful tool, especially for applications like high brightness LEDs, VCSELs and other optical devices but also for hard disc drives – e.g. next generation "patterned media" require sub-50nm concentric features printed onto various disc sizes with extreme pattern fidelity requirements. Both applications have been addressed already and feasibility is proven

## 4 REFERENCES


[1] Tomi Haatainen, Jouni Ahopelto, Gabi Grützner:" step&stamp imprint litho", SPIE3997-103

[2] Marc Verschuuren: " 3D photonic structure by sol-gel imprinting", MRS2008 San Jose

[3] Marc Verschuuren: " 3D photonic structure by sol-gel imprinting", MRS2008 San Jose